

### PULSE WIDTH MODULATION CONTROL CIRCUIT

The TL494 is a fixed frequency, pulse width modulation control circuit designed primarily for Switchmode power supply control.

This device features :

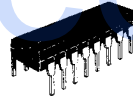
- Complete Pulse Width Modulation control circuitry
- On-chip oscillator with master or slave operation
- On-chip error amplifiers
- On-chip 5 volt reference
- Adjustable dead-time control
- Uncommitted output transistors capable of 200 mA current source or sink
- Output control for push-pull or single-ended operation

### ORDERING INFORMATION

PART NUMBER	TEMPERATURE RANGE	PACKAGE	
		DP	DG
TL494	0°C to +70°C	•	•
TL494I	-25°C to +85°C	•	•
Example : TL494DP, TL494DG			

### PULSE WIDTH MODULATION CONTROL CIRCUIT

#### CASE CB-79

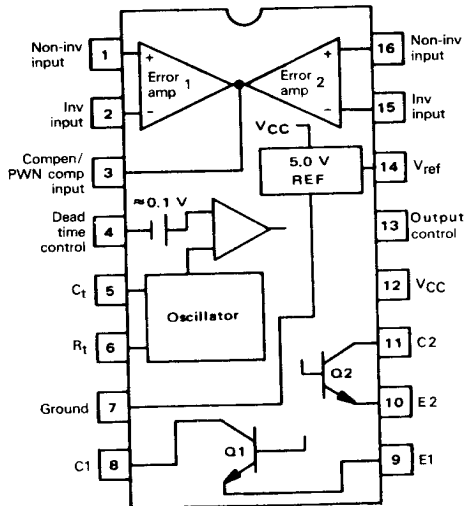


DP SUFFIX  
PLASTIC PACKAGE



DG SUFFIX  
CERDIP PACKAGE

### PIN ASSIGNMENT



**MAXIMUM RATINGS**

(Full operating ambient temperature range applies unless otherwise noted)

Rating	Symbol	TL494	TL494I	Unit
Power supply voltage	V <sub>CC</sub>	42	42	V
Collector output voltage	V <sub>C1</sub> , V <sub>C2</sub>	42	42	V
Collector output current (each transistor)	I <sub>C1</sub> , I <sub>C2</sub>	250	250	mA
Amplifier input voltage	V <sub>I</sub>	V <sub>CC</sub> + 0.3	V <sub>CC</sub> + 0.3	V
Power dissipation @ T <sub>amb</sub> ≤ 45°C	P <sub>tot</sub>	1000	1000	mW
Operating junction temperature	T <sub>J</sub>	+ 150	+ 150	°C
Operating ambient temperature range	T <sub>amb</sub>	0 to + 70	-25 to + 85	°C
Storage temperature range	T <sub>stg</sub>	-65 to + 150	-65 to + 150	°C

**THERMAL CHARACTERISTICS**

Characteristic	Symbol	Value	Unit
Junction-ambient thermal resistance	R <sub>th(j-a)</sub>	Cerdip package	100
		Plastic package	80
Junction-case thermal resistance	R <sub>th(j-c)</sub>	Cerdip package	25
		Plastic package	30

FIGURE 1 – BLOCK DIAGRAM

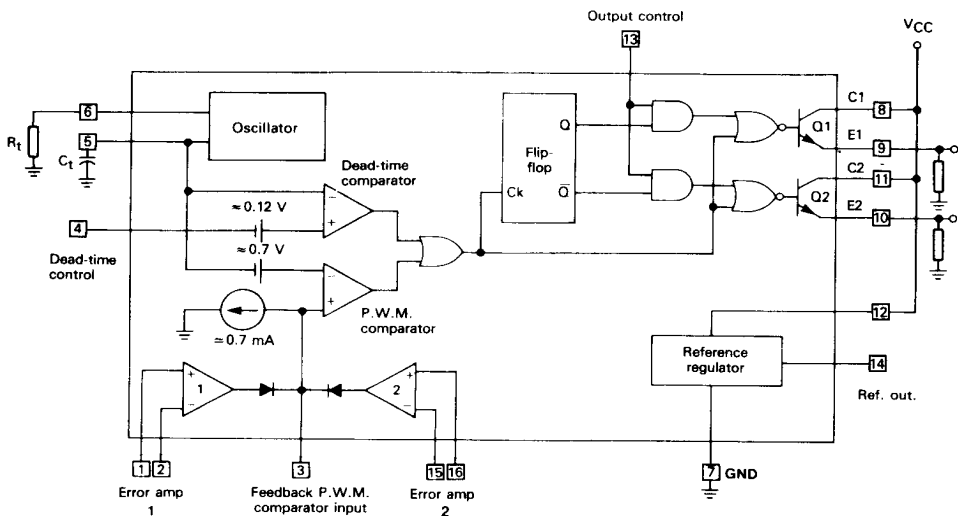
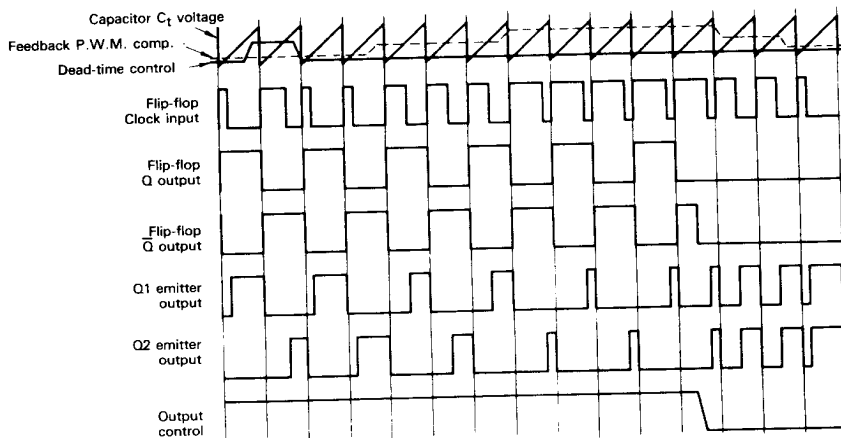


FIGURE 2 — TIMING DIAGRAMS



## DESCRIPTION

The TL494 is a fixed frequency pulse width modulation control circuit, incorporating the primary building blocks required for the control of a switching power supply. (See Figure 1.) An internal linear sawtooth oscillator is frequency-programmable by two external components,  $R_t$  and  $C_t$ . The oscillator frequency is determined by:

$$f_{osc} = \frac{1.1}{R_t \cdot C_t}$$

Output pulse width modulation is accomplished by comparison of the positive sawtooth waveform across capacitor  $C_t$  to either of two control signals. The NOR gates, which drive output transistors Q1 and Q2, are enabled only when the flip-flop clock-input line is in its low state. This happens only during that portion of time when the sawtooth voltage is greater than the control signals. Therefore, an increase in control-signal amplitude causes a corresponding linear decrease of output pulse width. (Refer to the timing diagrams shown in Figure 2.)

The control signals are external inputs that can be fed into the dead-time control, the error amplifier inputs, or the feedback input. The dead-time control comparator has an effective 120 mV input offset which limits the minimum output dead time to approximately the first 4% of the sawtooth-cycle time. This would result in a maximum duty cycle on a given output of 96% with the output control grounded, and 48% with it connected to the reference line. Additional dead time may be imposed on the output by setting the dead-time-control input to a fixed voltage, ranging between 0 to 3.3 V. The pulse width modulator comparator provides a

means for the error amplifiers to adjust the output pulse width from the maximum percent ON-time, established by the dead time control input, down to zero, as the voltage at the feedback pin varies from 0.5 to 3.5 V. Both error amplifiers have a common-mode input range from  $-0.3$  V to  $(V_{CC} - 2)$  V, and may be used to sense power-supply output voltage and current. The error-amplifier outputs are active high and are ORed together at the non-inverting input of the pulse-width modulator comparator. With this configuration, the amplifier that demands minimum output ON time, dominates control of the loop.

When capacitor  $C_t$  is discharged, a positive pulse is generated on the output of the dead-time comparator, which clocks the pulse-steering flip-flop and inhibits the output transistors, Q1 and Q2. With the output-control connected to the reference line, the pulse-steering flip-flop directs the modulated pulses to each of the two output transistors alternately for push-pull operation. The output frequency is equal to half that of the oscillator. Output drive can also be taken from Q1 or Q2, when single-ended operation with a maximum ON-time of less than 50% is required. This is desirable when the output transformer has a ringback winding with a catch diode used for snubbing. When higher output-drive currents are required for single-ended operation, Q1 and Q2 may be connected in parallel, and the output-mode pin must be tied to ground to disable the flip-flop. The output frequency will now be equal to that of the oscillator.

The TL494 has an internal 5 V reference capable of sourcing up to 10 mA of load current for external bias circuits. The reference has an internal accuracy of  $\pm 5\%$  with a thermal drift of less than 50 mV over an operating temperature range of 0 to  $+70^\circ\text{C}$ .

## RECOMMENDED OPERATING CONDITIONS

Characteristic	Symbol	Min	Typ	Max	Unit
Power supply voltage	$V_{CC}$	7.0	15	40	V
Collector output voltage	$V_{C1}, V_{C2}$	—	30	40	V
Collector output current (each transistor)	$I_{C1}, I_{C2}$	—	—	200	mA
Amplifier input voltage	$V_I$	-0.3	—	$V_{CC} - 2.0$	V
Current into feedback terminal	$I_{fb}$	—	—	0.3	mA
Reference output current	$I_{ref}$	—	—	10	mA
Timing resistor	$R_T$	1.8	30	500	k $\Omega$
Timing capacitor	$C_T$	0.00047	0.001	10	$\mu$ F
Oscillator frequency	$f_{osc}$	1.0	40	200	kHz

## ELECTRICAL CHARACTERISTICS

( $V_{CC} = +15$  V,  $f_{osc} = 10$  kHz unless otherwise specified).

For typical values  $T_{amb} = +25^\circ\text{C}$  for min./max values,  $T_{amb}$  is the operating ambient temperature range that applies unless otherwise specified.

## REFERENCE SECTION

Characteristic	Symbol	Min	Typ	Max	Unit
Reference voltage ( $I_O = 1.0$ mA, $T_{amb} = +25^\circ\text{C}$ )	$V_{ref}$	4.75	5.0	5.25	V
Reference voltage change with temperature over full operating temperature range	$\Delta I_{ref}(\Delta T)$	—	1.3	2.6	%
Line regulation ( $V_{CC} = +7.0$ V to $+40$ V)	$K_{VI}$	—	2.0	25	mV
Load regulation ( $I_O = 1.0$ mA to 10 mA)	$K_{VO}$	—	3.0	15	mV
Short-circuit output current ( $V_{ref} = 0$ V, $T_{amb} = +25^\circ\text{C}$ )	$I_{SC}$	—	35	—	mA

## OUTPUT SECTION

Characteristic	Symbol	Min	Typ	Max	Unit
Collector off-state current ( $V_{CC} = +40$ V, $V_{CE} = +40$ V)	$I_{C(off)}$	—	2.0	100	$\mu$ A
Emitter off-state current ( $V_{CC} = +40$ V, $V_C = +40$ V, $V_E = 0$ V)	$I_{E(off)}$	—	—	100	$\mu$ A
Collector-emitter saturation voltage Common-emitter ( $V_E = 0$ V, $I_C = 200$ mA) Emitter-follower ( $V_C = 15$ , $I_E = -200$ mA)	$V_{sat(C)}$ $V_{sat(E)}$	—	1.1 1.5	1.3 2.5	V
Output control pin current Low state ( $V_{OC} \leq 0.4$ V) High state ( $V_{OC} = V_{ref}$ )	$I_{OCL}$ $I_{OCH}$	—	10 0.2	— 3.5	$\mu$ A mA
Output voltage rise time Common-emitter (See Figure 12) Emitter-follower (See Figure 13)	$t_r$	—	100 100	200 200	ns
Output voltage fall time Common-emitter (See Figure 12) Emitter-follower (See Figure 13)	$t_f$	—	25 40	100 100	ns

**ERROR AMPLIFIER SECTIONS**

Characteristic	Symbol	Min	Typ	Max	Unit
Input offset voltage ( $V_O$ (Pin 3) = +2.5 V)	$V_{IO}$	—	2.0	10	mV
Input offset current ( $V_O$ (Pin 3) = +2.5 V)	$I_{IO}$	—	5.0	250	nA
Input bias current ( $V_O$ (Pin 3) = +2.5 V)	$I_{IB}$	—	0.1	1.0	$\mu$ A
Input common-mode voltage range ( $V_{CC}$ = +7.0 V to +40 V)	$V_{ICR}$	0.3	—	$V_{CC} - 2.0$	V
Open-loop voltage gain ( $\Delta V_O = 3.0$ V, $V_O = +0.5$ to +3.5 V, $R_L = 2.0$ k $\Omega$ )	$A_{VOL}$	70	95	—	dB
Unity-gain crossover frequency ( $V_O = +0.5$ to +3.5 V, $R_L = 2.0$ k $\Omega$ )	$f_C$	—	350	—	kHz
Phase margin at unity-gain ( $V_O = +0.5$ to +3.5 V, $R_L = 2.0$ k $\Omega$ )	$\varphi_m$	—	65	—	deg.
Common-mode rejection ratio ( $V_{CC} = +40$ V)	CMRR	65	90	—	dB
Power supply rejection ratio ( $\Delta V_{CC} = 33$ V, $V_O = +2.5$ V, $R_L = 2.0$ k $\Omega$ )	PSRR	—	100	—	dB
Output sink current ( $V_O$ (Pin 3) = +0.7 V)	$I_O^-$	0.3	0.7	—	mA
Output source current ( $V_O$ (Pin 3) = +3.5 V)	$I_O^+$	2.0	-4.0	—	mA

**PWM COMPARATOR SECTION** (Test Circuit Figure 11)

Characteristic	Symbol	Min	Typ	Max	Unit
Input threshold voltage (Zero duty cycle)	$V_{th}$	—	3.5	4.5	V
Input sink current (V (Pin 3) = +0.7 V)	$I_I^-$	0.3	0.7	—	mA

**DEAD-TIME CONTROL SECTION** (Test Circuit Figure 11)

Input bias current (Pin 4) - ( $V_I = 0$ to +5.25 V)	$I_{IB}$ (DT)	—	2.0	10	$\mu$ A
Maximum duty cycle, Each output, push-pull mode $V_I = 0$ V, $C_T = 0.1$ $\mu$ F, $R_T = 12$ k $\Omega$ $V_I = 0$ V, $C_T = 0.001$ $\mu$ F, $R_T = 30$ k $\Omega$	$DC_{max}$	45 —	48 45	50 50	%
Input threshold voltage (Pin 4) Zero duty cycle Maximum duty cycle	$V_{th}$	— 0	2.8 —	3.3 —	V

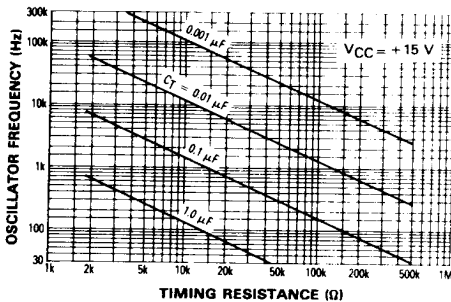
**OSCILLATOR SECTION**

Frequency ( $C_T = 0.001$ $\mu$ F, $R_T = 30$ k $\Omega$ )	$f_{osc}$	—	40	—	kHz
Standard deviation of frequency* ( $C_T = 0.001$ $\mu$ F, $R_T = 30$ k $\Omega$ )	$\sigma f_{osc}$	—	3.0	—	%
Frequency change with voltage ( $V_{CC} = +7.0$ V to +40 V, $T_{amb} = +25^\circ$ C)	$\Delta f_{osc}(\Delta V)$	—	0.1	—	%
Frequency change with temperature ( $\Delta T_{amb} = +25^\circ$ C to $T_{amb}$ low, +25 $^\circ$ C to $T_{amb}$ high)	$\Delta f_{osc}(\Delta T)$	—	1.0	2.0	%

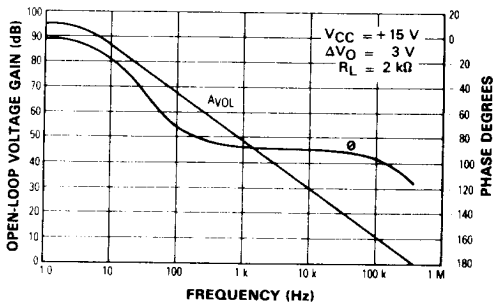
\* Standard deviation is a measure of the statistical distribution about the mean as derived from the formula

$$\sigma = \sqrt{\frac{\sum_{n=1}^N (X_n - \bar{X})^2}{N-1}}$$

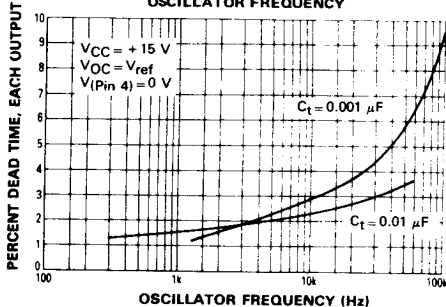
**FIGURE 3 – OSCILLATOR FREQUENCY VERSUS TIMING RESISTANCE**



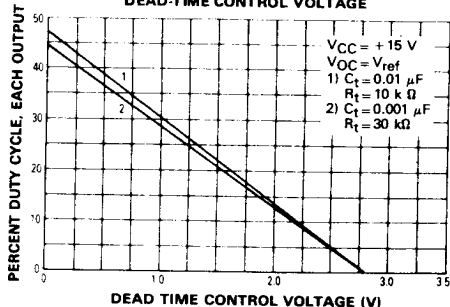
**FIGURE 4 – OPEN LOOP VOLTAGE GAIN AND PHASE VERSUS FREQUENCY**



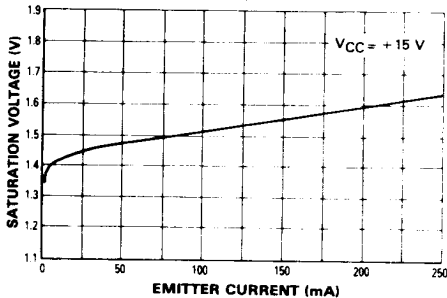
**FIGURE 5 – PERCENT DEAD TIME VERSUS OSCILLATOR FREQUENCY**



**FIGURE 6 – PERCENT DUTY CYCLE VERSUS DEAD-TIME CONTROL VOLTAGE**



**FIGURE 7 – EMITTER-FOLLOWER CONFIGURATION, OUTPUT-SATURATION VOLTAGE VERSUS EMITTER CURRENT**



**FIGURE 8 – COMMON-EMITTER CONFIGURATION, OUTPUT-SATURATION VOLTAGE VERSUS COLLECTOR CURRENT**

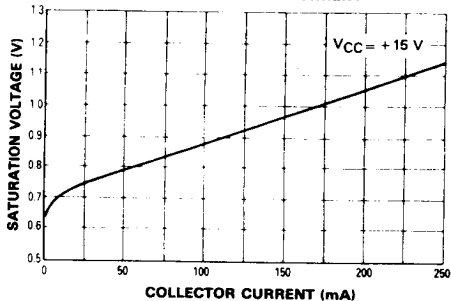


FIGURE 9 — STANDBY SUPPLY CURRENT VERSUS SUPPLY VOLTAGE

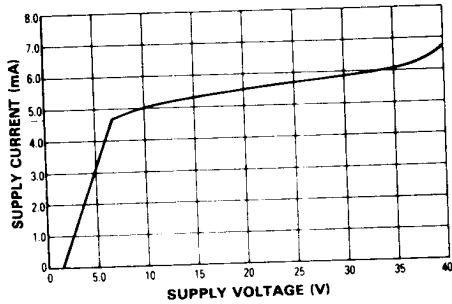


FIGURE 10 — ERROR AMPLIFIER CHARACTERISTICS

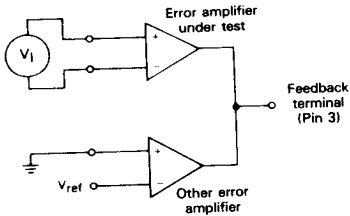


FIGURE 11 — DEAD-TIME AND FEEDBACK CONTROL TEST CIRCUIT

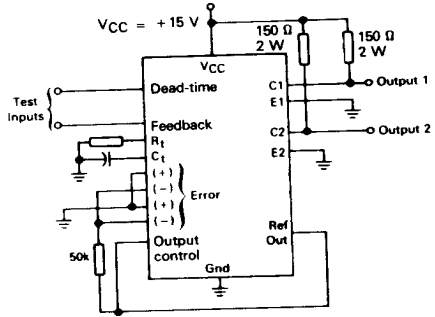


FIGURE 12 — COMMON-EMITTER CONFIGURATION TEST CIRCUIT AND WAVEFORM

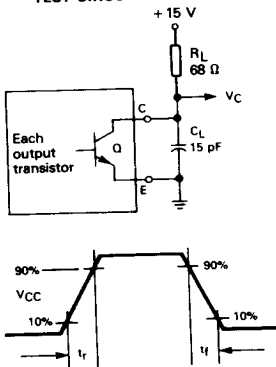


FIGURE 13 — EMITTER-FOLLOWER CONFIGURATION TEST CIRCUIT AND WAVEFORM

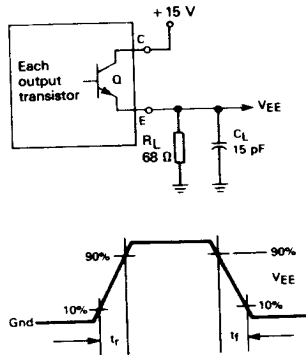


FIGURE 14 — ERROR-AMPLIFIER SENSING TECHNIQUES

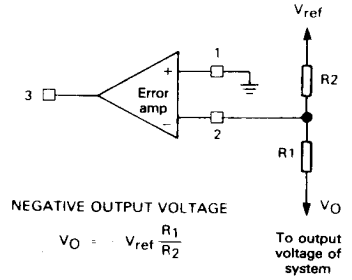
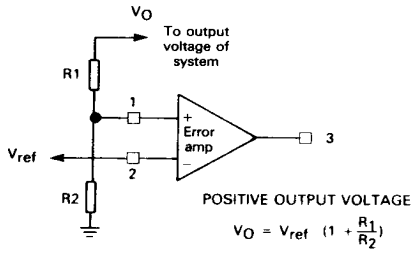
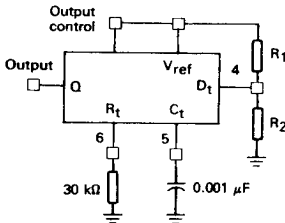


FIGURE 15 — DEAD-TIME CONTROL CIRCUIT



$$\text{Max \% ON Time, Each output} \approx 45 \left( \frac{80}{1 + \frac{R_1}{R_2}} \right)$$

FIGURE 16 — SOFT-START CIRCUIT

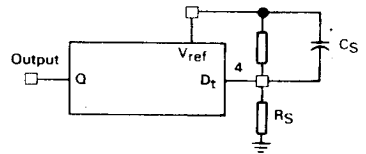


FIGURE 17 — OUTPUT CONNECTIONS FOR SINGLE-ENDED AND PUSH-PULL CONFIGURATIONS

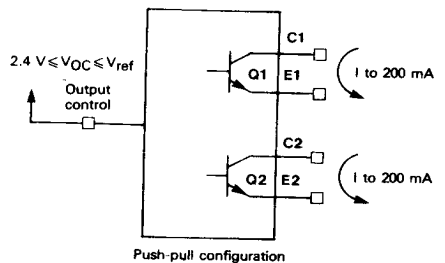
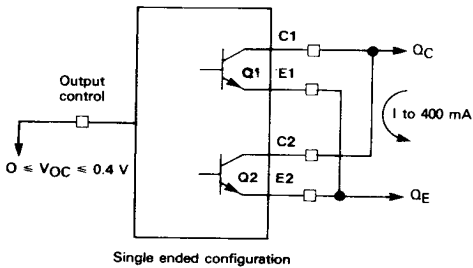




FIGURE 18 — SLAVING TWO OR MORE CONTROL CIRCUITS

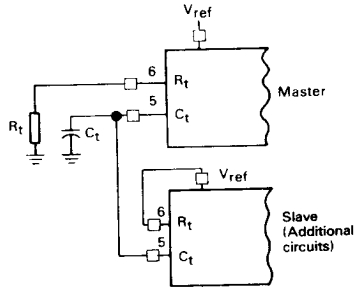
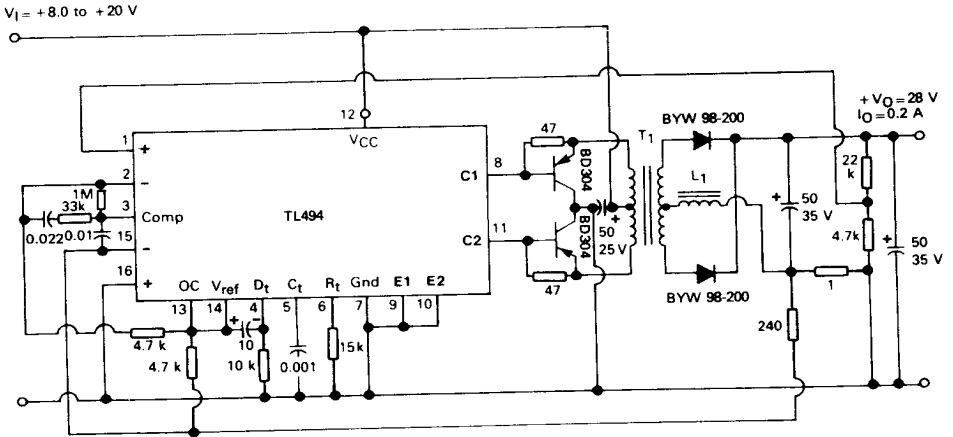


FIGURE 19 — PULSE-WIDTH MODULATED PUSH-PULL CONVERTER



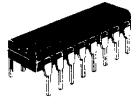
All capacitors in  $\mu\text{F}$ , resistors in  $\Omega$  unless otherwise specified

- L1 — 3.5 mH @ 0.3A
- T1 — Primary: 20T C.T. #28 AWG  
Secondary: 120T C.T. #36 AWG
- Core : T22 - FP 14 x 8 - SE ' FERRINOX®
- LCC COMPONENTS

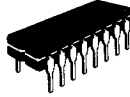
TEST	CONDITIONS	RESULTS
line regulation	$V_1 = +8.0$ to $+20$ V	3.0 mV 0.01 %
Load regulation	$V_1 = +12.6$ V, $I_O = 0.2$ to 200 mA	5.0 mV 0.02 %
Output ripple	$V_1 = +12.6$ V, $I_O = 200$ mA	40 mVpp
Short circuit current	$V_1 = +12.6$ V, $R_L = 0.1 \Omega$	250 mA
Efficiency	$V_1 = +12.6$ V, $I_O = 200$ mA	72 %



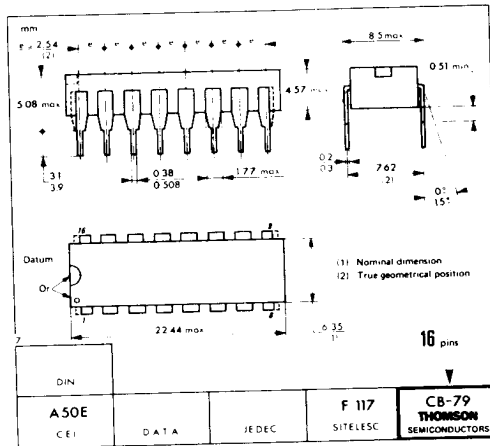
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